HOT-WIRE TYPE AIR FLOW METER FOR

INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a measuring apparatus of an air flow rate and, more particularly, to a hot-wire type air flow meter (heat flow meter) suitable for detection of a suction air flow rate of an internal combustion engine.

Description of Related Art

Hitherto, as an air flow rate measuring apparatus which is provided for an electronic control type fuel injection apparatus of an internal combustion engine such as an automobile or the like and measures a suction air flow rate, a number of hot-wire type apparatuses have been used because a mass air flow rate can be directly detected. In this instance, to assure a reliability of an exothermic resistor, a sensor having a certain extent of heat capacity which is constructed by winding a platinum wire around a bobbin and coating it with glass, forming a thin film resistor onto a ceramic substrate, or the like is often used. In a sensor having a large heat capacity, although a system such that a current is limited when a waterdrop is deposited onto a portion other than an internal combustion engine has been shown in JP-A-5-264312, a power voltage is large to be 24V and a measuring region

of a rated value or more is limited. Such a system is used, particularly, for measurement of a flow rate of the compressed air and there is a problem that although a waterdrop is instantaneously evaporated usually at

5   100°C at an atmospheric pressure, in the compressed air, an evaporation temperature of the water is high, it takes time to evaporate the waterdrop, and an excessive current flows in an exothermic portion. In this instance, since the power voltage is high to be 24V,

10   when a waterdrop is deposited, a current which is one or more digits larger than a rated current flows, and accordingly, it is limited by a current limiter. In an internal combustion engine, to prevent a fusion of a hot wire, a system for reducing an applied voltage to a

15   bridge by detecting a voltage across a hot wire resistor has been disclosed in JP-A-61-102522 or the like. According to such a system, to prevent the fusion due to the supply of the abnormal voltage because of noises or the like, a voltage limit value

20   larger than the maximum value at the time of the stationary operation is set.

As a flow meter having a high response speed, a number of flow meters in which an exothermic resistor of a small heat capacity is attached on a silicon

25   substrate have been proposed. For example, as shown in JP-B-5-7659, a thin film is formed on a silicon semiconductor substrate and a flow rate is detected by a thermal sensor.

SUMMARY OF THE INVENTION

In the conventional techniques mentioned above, in case of using an exothermic resistor of a large heat capacity, a response speed at the time of a power-on of an air flow rate measuring apparatus is determined only from the relation between a power source voltage and the heat capacity of the exothermic resistor. In an internal combustion engine such as an ordinary gasoline engine or the like, therefore, since a power source voltage is usually small to be about 12V, an operating current to the exothermic resistor is limited and it takes time to heat, so that it is difficult to accurately measure an air flow rate for a predetermined time at the start of an engine of an automobile or the like.

To improve the response speed, it is necessary to use an exothermic resistor of a small heat capacity. In a hot-wire air flow meter, however, the maximum flow rate which can be measured is limited unconditionally to a certain degree by the heat capacity and a heating temperature of the exothermic resistor which is used for measurement and by a power source voltage which can be applied. It is because when the heat capacity is small, if it is intended to raise a measuring sensitivity (maximum flow rate) of the flow rate by increasing the heating temperature, a limitation such that the exothermic resistor

deteriorates when the heating temperature is equal to
or higher than a predetermined value occurs. For
example, a system such that an exothermic resistor is
constructed by forming a thin film with a diaphragm

5 structure onto a silicon substrate and a temperature of
the exothermic resistor is controlled so as to become a
constant temperature by a feedback circuit by using a
bridge circuit or the like has the highest response
speed. If a waterdrop, an oil droplet, or the like is

10 deposited onto the exothermic resistor portion,
however, a heating balance is broken and a voltage is
applied so that the heating temperature of the
exothermic resistor locally rises. Even in case of the
applied voltage which does not cause a problem in the

15 ordinary operation, therefore, if the temperature
elevation continues, there is a possibility that the
resistor of a small heat capacity constructed by the
thin film is deteriorated by the heat and, in the worst
case, the diaphragm is broken by a thermal stress.

20   Although the excessive temperature elevation
can be prevented by limiting the voltage applied to the
hot-wire type resistor so as not to locally raise the
heating temperature of the exothermic resistor, there
is a problem that a measuring range of the inherent

25 flow rate is also narrowed.

      It is, therefore, an object of the invention
to provide a hot-wire type air flow meter for an
internal combustion engine which can solve the problems

of the conventional techniques mentioned above.

According to an aspect of the invention, there are provided: means for detecting a heating state of an exothermic resistor by distinguishing a case where a waterdrop, an oil droplet, or the like is deposited onto the exothermic resistor portion from a normal case where there is no deposition; and circuit means for limiting a heating time by the detected heating state. Thus, only in the case where the waterdrop, oil droplet, or the like is deposited onto the exothermic resistor portion, the heating state is limited without narrowing a measuring range of an inherent flow rate and a deterioration of the resistor can be prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram showing an example of a hot-wire type flow meter according to the first embodiment of the invention;

Figs. 2A and 2B are diagrams each showing the limiting operation at the time when a waterdrop is deposited and a flow rate measuring range;

Fig. 3 is a diagram showing output voltage characteristics of a bridge potential difference and a differential amplifier;

Figs. 4A to 4D are comparison diagrams of the voltage limiting operations of a bridge voltage at the time of power-on;

Fig. 5 is a diagram showing a burn-out region according to a temperature and a hot flow rate;

Figs. 6A and 6B are comparison diagrams of the voltage limiting operations of the bridge voltage at the time of power-on in the case where it has a temperature characteristic;

Fig. 7 is a diagram of an example showing a pattern of a resistor formed on a silicon substrate;

Fig. 8 is a cross sectional view of an example of the resistor formed on the silicon substrate;

Fig. 9 is a circuit diagram showing an example of a hot-wire type air flow meter according to the second embodiment of the invention;

Figs. 10A to 10F are comparison diagrams of the voltage limiting operations of a bridge voltage at the time of power-on;

Fig. 11 is a diagram showing an example of a pattern of a resistor formed on a silicon substrate;

Fig. 12 is a circuit diagram showing an example of a hot-wire type flow meter according to the third embodiment of the invention;

Fig. 13 is a diagram showing a state where a resistor formed on a silicon substrate is mounted on a circuit board; and

Fig. 14 is a circuit diagram showing an example of a hot-wire type flow meter according to the fourth embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

An embodiment of a hot-wire type air flow meter for an internal combustion engine according to

5   the invention will be described in detail hereinbelow. In the following drawings, component elements having the same or similar functions are designated by the same reference numerals.

An example of a construction of a hot-wire

10   type air flow meteraccording to the first embodiment of the invention will be described hereinbelow with reference to Fig. 1. A hot wire driving circuit 1 is connected to a power source 101 and generates a signal corresponding to an air flow rate. A hoisten-bridge

15   circuit is constructed by: an exothermic resistor 11; a temperature compensation resistor (a resistor for measuring a suction air temperature, a temperature detecting element of a fluid, a temperature sensor of an air and a medium, a fluid temperature sensing unit,

20   a temperature dependent resistor) 12 as a resistor whose resistance value varies in accordance with an ambient air temperature; and resistors 13 and 14. The hot wire driving circuit 1 is constructed in such a manner that a current flowing in the exothermic

25   resistor 11 is adjusted by a differential amplifier 15 and a transistor 16 so that a potential difference at a middle point of a bridge is equal to zero by the hoisten-bridge circuit. When a heating temperature of

the exothermic resistor 11 is low, an output of the
differential amplifier 15 is large and the resistor 11
operates so as to heat more. With this construction,
the resistance value of the exothermic resistor 11 is

5 controlled so as to be constant irrespective of an air
flow rate, namely, in a manner such that the
temperature is set to a predetermined value. In this
instance, a signal corresponding to an air flow rate
due to the exothermic resistor 11 is inputted to a zero

10 span circuit 2. The zero span circuit 2 is constructed
by a differential amplifier 21 and resistors 22, 23,
24, 25, 26, and 27.

The exothermic resistor 11 can be constructed
by, for example, a thin or thick film of platinum or

15 tungsten as an exothermic body onto a plate-shaped
glass or ceramic substrate. It is, however, necessary
to design it so as to have a small heat capacity.

Particularly, to reduce the heat capacity and
raise a response speed, it is desirable to construct

20 the exothermic resistor 11 in such a manner that a thin
or thick film of platinum or tungsten, a polysilicon
resistor, or a resistor of monocrystal silicon is
formed as an exothermic body onto a thin portion of a
semiconductor substrate of silicon or the like.

25 The exothermic resistor 11 is provided in a
suction passage of an internal combustion engine of an
automobile or the like and a voltage output
corresponding to a flow rate of the air flowing in the

suction passage is obtained as an output of the differential amplifier 21. An ordinary hot-wire type air flow meter is constructed as mentioned above.

A measuring range of the air flow rate in
5 case of preventing a deterioration, breakage, or the like of the resistor due to overheating will now be described with reference to Fig. 2A. This diagram shows the relation between the flow rate and a voltage (or current) which is applied to the exothermic
10 resistor due to an increase in flow rate. An output according to the flow rate becomes an output of the hot-wire type air flow meter. Now, considering an operating state at the time when a waterdrop is deposited, it is necessary to limit the voltage to a
15 value which is equal to or less than a voltage (or current) at which a deterioration, breakage, or the like is caused in the resistor by the deposition of the waterdrop. A limiter limits the voltage to a value which is equal to or less than such a voltage. In this
20 case, by limiting the voltage by the limiter, a specified measuring range of the air flow rate is simultaneously limited. Particularly, in case of using an exothermic resistor of a small heat capacity constructed by forming a thin film onto a silicon
25 semiconductor substrate, since the voltage (or current) at which a deterioration, breakage, or the like is caused in the resistor by the deposition of the waterdrop drops, there is a tendency such that the

measuring range is narrowed.

On the other hand, to widen the measuring range to the voltage (or current) at which a deterioration, breakage, or the like is caused in the resistor by the deposition of the waterdrop, it is possible to cope with such a purpose by detecting a depositing state of the waterdrop and limiting the voltage (or current) in accordance with the presence or absence of the waterdrop. Fig. 2B shows a measuring range of the air flow rate in this instance. Particularly, in case of using an exothermic resistor of a small heat capacity constructed by forming a thin film onto a silicon semiconductor substrate, to widen the measuring range to the voltage (or current) at which a deterioration, breakage, or the like is caused in the resistor by the deposition of the waterdrop, it is necessary to increase a rated value and set a limiting condition (first limiter) such as a voltage (or current) or the like to a rated value (maximum specified measuring range) or more. In this state, however, since a breakage or the like is caused at the time of deposition of a waterdrop, second limiting means for limiting the voltage to a value which is equal to or less than a rated value at which a breakage or the like is not caused by the voltage (or current) when a deposition of a waterdrop is detected is provided. Particularly, as a level of the second limiter, it is especially effective to set the voltage

to a level so as not to cause a state called "burn-out" such that when a waterdrop is deposited, an air layer is formed on the surface of the exothermic resistor and overheating occurs.

5   As shown in Fig. 1, in the embodiment, a Zener diode 44 is provided as a first limiter for limiting the voltage within the measuring range of the flow rate or more. The Zener diode limits the voltage when a battery voltage of the power source 101 rises,

10   and it does not operate ordinarily.

In this instance, particularly, a differential amplifier 68 is prepared as second bridge detecting means for detecting a potential difference at a middle point of the bridge in order to detect the

15   depositing state of the waterdrop, and a voltage limitation switching circuit 6 is provided as a second limiter for limiting an output voltage V3 of the differential amplifier 15 in accordance with a detection result. Fig. 3 shows characteristics of the

20   bridge potential difference and the output voltage of the differential amplifier as input/output characteristics of the bridge circuit.

Usually, the current flowing in the exothermic resistor 11 is adjusted by the differential

25   amplifier 15 and transistor 16 so that an output (potential difference at the middle point of the bridge) of the bridge circuit is equal to zero. It is because the voltage which is applied to the bridge

circuit is controlled within a range from 0 to the power source voltage by a feedback in accordance with the potential difference at the middle point of the bridge. When the potential difference input at the

5 middle point of the bridge is equal to or larger (or smaller) than a predetermined value, the output of the differential amplifier 15 is limited to the power source voltage or grounding level.

In the ordinary operation, since there is an

10 output sensitivity only for the potential difference (+dV) of the bridge on the plus side, it is difficult to distinguish the bridge potential difference (+dV) when the waterdrop is deposited from the bridge potential difference (+dV) which is temporarily

15 generated at the time of the maximum flow rate. Therefore, attention is paid to the fact that a large bridge voltage is continuously generated when the waterdrop is deposited, and the output voltage is limited by the limiter only in this case.

20 Since it is actually difficult to limit the output voltage only by the differential amplifier 15, the differential amplifier 68 is added and used as a detector of the waterdrop and as a limiter. Specifically speaking, the differential amplifier 68 is

25 constructed in such a manner that a polarity of the potential difference at the middle point of the bridge is changed and (-dV) is inputted, namely, the potential difference at the middle point of the bridge is changed

to the opposite polarity and (-dV) is inputted, when the large bridge potential difference (+dV) is continuously generated, the output of the differential amplifier 68 is set to the grounding level and the

5 second limiter is made operative, and the second limiter is made inoperative in the other cases. Since there is generally an offset voltage in the input of the differential amplifier, a partial region of the bridge potential difference crosses.

10 As mentioned above, for the ordinary control voltage range (only from 0V to the power source voltage and the plus side) of the voltage to be applied to the bridge circuit, the potential difference at the middle point of the bridge is outputted as a differential

15 amount between the plus side and the minus side. Therefore, the polarities on the plus side and the minus side of the potential difference at the middle point of the bridge are shared by the two differential amplifiers 15 and 68 and such a potential difference is

20 separately inputted and fed back to the voltage which is applied to the bridge circuit. Consequently, if a state where the potential difference at the middle point of four resistors constructing the bridge circuit is equal to, for example, 100 mV or more or 100 mV or

25 less continues, it is possible to determine that such a state is a certain specific state (for example, waterdrop depositing state).

The voltage limitation switching circuit 6 is

constructed by: resistors 61, 62, and 63 connected serially between a battery voltage VB of the power source 101 and the ground; a Zener diode 67 connected to a node of the resistors 62 and 63; diodes 65 and 66

5 connected to a node of the resistors 61 and 62; and the like. The voltage limitation switching circuit 6 limits the output of the differential amplifier 15 to a voltage V7 which is set by the Zener diode 67 through a resistor 17, the diode 66, and the resistor 62. If a

10 resistor having a temperature coefficient which is equal to or larger than that of the temperature compensation resistor 12 is used as a resistor 62 and arranged in a suction pipe, the temperature characteristic can be also provided at the voltage V7

15 which is set by the Zener diode 67.

An example will now be specifically described. In the case where the exothermic resistor 11 is controlled at a constant temperature in the ordinary operation, a potential difference dV at the

20 middle point of the bridge approaches zero. Assuming that the offset voltage of the differential amplifier 15 is equal to plus several mV, dV is stabilized at a level of minus several mV. Even in the case where the flow rate increases and potential difference dV

25 slightly increases, by rapidly increasing the heating current of the exothermic resistor 11 on the basis of the output of the differential amplifier 15 and always making the constant temperature control, the potential

difference dV at the middle point of the bridge is held

at the level of minus several mV near zero. In this

instance, assuming that the potential difference dV at

the middle point of the bridge is held at the level of

5 minus several mV, the output of the differential

amplifier 68 to detect the depositing state of the

waterdrop is set to the high level. Assuming that both

of the differential amplifier 15 and differential

amplifier 68 are connected to the power source 101 by

10 similar circuit constructions, an output V3 of the

differential amplifier 15 is not subjected to the

voltage limitation by the operations of the diodes 65

and 66 of the voltage limitation switching circuit 6.

On the other hand, when a waterdrop is deposited, since

15 the heating temperature of the exothermic resistor 11

does not rise, the large potential difference dV at the

middle point of the bridge of plus hundreds of mV is

generated. When this state is detected, the output of

the differential amplifier 68 is set to the low level.

20 The output V3 of the differential amplifier 15 is

subjected to the voltage limitation by the voltage V7

set by the resistors 61, 62, and 63 and Zener diode 67

by the operation of the voltage limitation switching

circuit 6.

25　　　　Subsequently, the details of the voltage

limiting operation using the voltage limitation

switching circuit 6 will be described with reference to

Figs. 4A to 4D. Figs. 4A and 4B show the operations of

the potential difference dV at the middle point of the bridge and the output V3 of the differential amplifier 15 in the normal operation, respectively. The output V3 of the differential amplifier 15 becomes maximum and
5 the potential difference dV also increases for a time T1 during which the exothermic resistor 11 is heated upon activation. After that, when the initial heating is finished, the stable constant temperature control operation is performed after the elapse of a time T2,
10 the potential difference dV decreases, and the output V3 of the differential amplifier 15 is stabilized to a predetermined voltage according to the flow rate. For example, in case of the exothermic resistor of the small heat capacity constructed by forming the thin
15 film onto the silicon semiconductor substrate, the time T2 which is required until the control operation is stabilized after the end of the initial heating can be set to a short time within a range from several msec to tens of msec in accordance with the heat capacity.
20 In the voltage limiting operation in Figs. 4C and 4D, a difference due to the presence or absence of the voltage limiting operation when a waterdrop is deposited according to the embodiment will be described. First, a case of no voltage limitation will
25 be explained. When a waterdrop is deposited, the output V3 of the differential amplifier 15 becomes the maximum voltage upon activation and its state is almost maintained although there is a slight fluctuation until

the water is evaporated and the ordinary operation is
performed (refer to Fig. 4D). For this period of time,
although the potential difference dV at the middle
point of the bridge increases upon activation, the

5   unstable operation such that it is decreased and
increased is repeated after that (refer to Fig. 4C).
It is because if the voltage applied to the bridge is
large, when a waterdrop is deposited, an air layer is
partially formed on the surface of the exothermic

10 resistor and a state called "burn-out" corresponding to
overheating occurs. The exothermic resistor repeats
the quenching by the waterdrop and the partial high
temperature heating state by the air layer. The
potential difference dV at the middle point of the

15 bridge also repetitively increases and decreases in
accordance with the heating state of the exothermic
resistor. The reason why the potential difference dV
increases and decreases is because the heating
temperature rises due to the formation of the air layer

20 and such a state is temporarily recognized as an
ordinary balanced control situation of the bridge. In
this state, if the potential difference dV at the
middle point of the bridge is merely checked, the
depositing state of the waterdrop cannot be

25 discriminated. If the temperature continuously rises,
the resistor of the small heat capacity formed by the
thin film is deteriorated by the heat or the breakage
of the diaphragm cannot be prevented due to the heat

stress.

On the other hand, a case where there is a
voltage limitation will be described. When the
waterdrop is deposited, if the potential difference dV

5   at the middle point of the bridge is large, the output
V3 of the differential amplifier 15 is limited by the
voltage limitation switching circuit 6. That is, when
the waterdrop is deposited, the bridge applied voltage
is limited to a predetermined value or less so that an

10   electric power can be limited to a predetermined power
corresponding to the area of the exothermic resistor or
less so as not to cause a state called "burn-out"
indicative of an overheating in which the air layer is
formed on the surface of the exothermic resistor.

15   Thus, if the state where the potential difference dV at
the middle point of the bridge is large continues and
there is no waterdrop, the potential difference dV
decreases and the voltage limitation is cancelled.
Therefore, by limiting the bridge applied voltage in

20   accordance with the potential difference dV upon
activation and monitoring the magnitude of the
potential difference dV, the depositing state of the
waterdrop can be discriminated. If the predetermined
voltage or more is applied even in a state where the

25   output V3 of the differential amplifier 15 is limited
to VB2, the waterdrop can be evaporated after the
elapse of the predetermined time T1. Even if there is
the waterdrop, the deterioration or breakage of the

exothermic resistor can be prevented and, at the same

time, by eliminating the waterdrop, the operation can

be certainly returned to the stable constant

temperature control operation after the elapse of the

5   time T2. The duration of the time T2 varies depending

on the depositing state or amount of waterdrop. It is

sufficient to set a predetermined electric power level

according to the area of the exothermic resistor to a

voltage (or current) at which it can be limited to a

10   value of a heat flux of, for example, 4×10^5 W/m^2 or

less so as not to cause the state called "burn-out"

mentioned above.

The operation in the case where the initial

temperature of the deposited waterdrop varies depending

15   on the ambient temperature will now be described. Fig.

5 shows a state where in the case where the front

surface of the exothermic resistor is covered by a

waterdrop, the higher the temperature of the waterdrop

(regarded in a manner similar to the suction

20   temperature) is, the smaller the value of the heat flux

causing the burn-out is. In other words, it means that

when the temperature is high, even if the electric

power which is applied to the exothermic resistor is

small, the burn-out more easily occurs. Therefore, by

25   using the resistor having the temperature

characteristic as a resistor 62 in Fig. 1 as shown in

Figs. 6A and 6B, the limiting voltage can be also

varied in accordance with the suction temperature. In

this case, when the suction temperature in Fig. 6A is
low, a limiting voltage VB3 is increased (a difference
between the limiting voltage and the voltage at the
time of no limitation is small). In this case, when

5   the suction temperature in Fig. 6B is high, a limiting
voltage VB4 is decreased (the difference between the
limiting voltage and the voltage at the time of no
limitation is large). By this method, the
deterioration or breakage of the resistor due to the

10   burn-out or the like in various modes can be prevented.
           Even if the fuel flows at the maximum flow
rate and the heating temperature of the exothermic
resistor decreases, the potential difference dV
instantaneously increases and the bridge applied

15   voltage is limited. However, since the heating
temperature is soon recovered in the ordinary air, the
potential difference dV decreases and the limitation of
the bridge applied voltage is soon eliminated.
Therefore, there is no practical problem.

20   According to the embodiment, particularly, by
detecting the depositing state of the waterdrop and
limiting the applied voltage, there are effects such
that the deterioration of the reliability such as
deterioration or breakage of the exothermic resistor

25   can be prevented and the measuring range of the flow
rate can be widened. Although the circuit is not
particularly shown in the diagram, even in case of
using a circuit construction such that a plurality of

bridge circuits of the exothermic resistor are provided and a reverse current can be detected, it is sufficient to add a voltage limiting circuit of the invention every bridge circuit. Similarly, even in case of using

5 an indirect-heated type construction in which the exothermic resistor and the bridge circuit of a constant temperature control circuit are separately provided, similar effects can be obtained by detecting the potential difference of the bridge and adding the

10 voltage limiting circuit of the invention to the exothermic resistor. Although the limitation of the voltage has been described in the embodiment, similar effects can be also obtained by limiting the current which is supplied to the bridge.

15   Fig. 7 shows an example of a pattern in the case where the exothermic resistor 11 which is used is constructed by forming a thin film onto the silicon semiconductor substrate. An exothermic resistor 211a is vertically elongated, has a pattern in which a

20 resistor is turned back, and has a structure in which resistors 211d, 211e, 211f, and 211g for detecting a temperature are arranged on both sides of the pattern. Each of the exothermic resistor 211a and the temperature detecting resistors 211d, 211e, 211f, and

25 211g is formed, for example, by arranging a resistor onto a diaphragm structure portion having a small heat capacity etched from the back side of a silicon substrate. A temperature compensation resistor 211c is

arranged at a location where it is hardly influenced by the temperature by the heating of the exothermic resistor 211a. Dimensions of the diaphragm in case of reducing the heat capacity are set such that, for

5 example, a length in the vertical direction lies within a range from 1.8 μm to 3 μm, a width lies within a range from 0.5 μm to 0.8 μm, and a thickness lies within a range from 1 μm to 3 μm. By setting the dimensions as mentioned above, the heat capacity is

10 small and a strength of the diaphragm can be easily assured. Fig. 8 shows a cross sectional structure taken along the line VIII-VIII of the exothermic resistor in Fig. 7. The diaphragm has a structure such that a thickness of the place where the resistor

15 pattern exists is largest. It is considered that a size of waterdrop having a possibility that it is deposited onto the exothermic resistor through an air filter of an automobile is usually smaller than a size (for example, 20 μm) of a mesh of the air filter.

20 However, in the case where a dew condensation due to a sudden temperature change or the waterdrop formed via the filter is collected by some form in accordance with a shape or the like of the filter and grows, it is considered that the waterdrop of a size of up to about

25 several ml is deposited. For example, in the diaphragm according to the foregoing example, when a waterdrop of 1 ml is deposited, it is considered that it covers an area in a range from about 1/5 to 1/2 of the exothermic

resistor of the diaphragm. In such a case, an air bubble is more easily produced by the burn-out.

Fig. 9 shows the second embodiment in case of using such a resistor pattern. The hot wire driving circuit 1 is constructed in such a manner that a current flowing in the exothermic resistor 211a is adjusted by the differential amplifier 15 and transistor 16 so that the potential difference at the middle point of the bridge is equal to zero by a hoisten-bridge circuit constructed by the exothermic resistor 211a, temperature compensation resistor 211c, and resistors 13 and 14.

The resistors 211d, 211e, 211f, and 211g for detecting a temperature construct a bridge circuit by applying a voltage Vcc to a power source circuit 5. As a voltage which is applied to the bridge circuit, it is also possible to form a ratio metric construction using an external voltage. This differential voltage is amplified by a differential amplifier 2131 and resistors 2132, 2133, 2134, and 2137 around a virtual zero point voltage Vof, as a center, obtained by dividing a reference voltage Vref by resistors 2135 and 2136. Although the temperature detecting resistors 211d, 211e, 211f, and 211g detect the heating temperature of the exothermic resistor 211a, since a temperature distribution becomes uniform in the case where there is no air flow, an output Vbi of the differential amplifier 2131 is equivalent to the

virtual zero point voltage Vof. When an air flow

occurs here, by arranging the exothermic resistor 211a

so that its longitudinal direction is perpendicular to

the direction of the air flow, a temperature difference

5   occurs between the resistors 211d and 211e and the

resistors 211f and 211g, so that a flow rate signal

according to the direction of the flow can be obtained

as an output Vbi of the differential amplifier 2131.

        In the embodiment, particularly, the output

10   Vbi of the differential amplifier 2131 is inputted to

an analog/digital converter 221 of a microcomputer 220,

a variation or the like of an output sensitivity is

adjusted as a digital amount by an arithmetic

operation, and a resultant signal is sent to an engine

15   control unit or the like as an output voltage Vout of a

digital/analog converter 224. The microcomputer 220 is

constructed by: an arithmetic operating circuit 222

comprising a CPU 222a and memories, for example, an RAM

222b and an ROM 222c; an oscillator (OSC) 226; an

20   input/output (I/O) unit 225; a memory, for example, a

PROM 223; and the like. It is sufficient to use a

memory which can record a variation or the like of an

output sensitivity of each sensor as an adjustment

value one or more times as a PROM 223. The PROM 223 is

25   not limited only to an electrically writable EEPROM, a

flash ROM, or the like.

        Voltages Vr1 and Vr2 at both ends of the

exothermic resistor 211a, an output Vr3 of the

differential amplifier 15, and the output Vbi of the differential amplifier 2131 are inputted to the analog/digital converter 221 of the microcomputer 220. In the microcomputer 220, the heating state of the

5   exothermic resistor 211a is detected by obtaining the heating temperature by an arithmetic operation from the voltages Vr1 and Vr2 at both ends of the exothermic resistor 211a, an NPN transistor 43 is turned on by the output V6 of the I/O unit 225, and the heating state of

10 the exothermic resistor 211a is limited by the voltage limitation switching circuit 6. Particularly, an SCI (Serial Communication Interface) 227 for communicating with the engine control unit or the like is provided for the microcomputer 220.

15   The voltage limitation switching circuit 6 is constructed by: the resistors 61 and 63 serially connected between the battery voltage VB of the power source 101 and the ground; the Zener diode 67 connected to a node of a resistor 211h (62) and the resistor 63;

20 the diodes 65 and 66 connected to a node of the resistors 61 and 62; a resistor 64 connected to the battery voltage VB; the NPN transistor 43; and the like. The resistor 211h can be constructed in a manner similar to the temperature compensation resistor 211c.

25   The voltage limitation switching circuit 6 limits the output V3 of the differential amplifier 15 to a voltage which is set by the Zener diode 67 via the diode 66 and resistor 62. Since the NPN transistor 43

is OFF in the normal operation, the diode 65 is

connected to the battery of the power source 101 via

the resistor 64. Thus, in the normal operation, the

output V3 of the differential amplifier 15 is not

5   subjected to the voltage limitation. On the other

hand, by detecting the heating temperature of the

exothermic resistor and discriminating the heating

state, the NPN transistor 43 is turned on and the

output V3 of the differential amplifier 15 can be

10   limited to the voltage set by the Zener diode 67 via

the diode 66 and resistor 62.

The details of the second embodiment will now

be described with reference to Figs. 10A to 10F. It

corresponds to a case where the exothermic resistor

15   211a is heated from the ordinary temperature and the

constant temperature control of about 200°C is made as

in case of turning on the power source. The case of

the normal operation in Figs. 10A to 10C will be

described. When the maximum current which is limited

20   by the battery voltage VB flows in the exothermic

resistor 211a, the exothermic resistor 211a is rapidly

heated (Fig. 10A). A resistance value Rh1 increases

due to the temperature elevation, the bridge circuit is

balanced, and the output V3 of the differential

25   amplifier 15 decreases (Fig. 10C). The time T1 during

which the maximum current flows in the exothermic

resistor 211a is determined only by the resistance

value Rh1 and heat capacity of the exothermic resistor

211a and the battery voltage VB in the ordinary case.
The smaller the heat capacity is, the shorter the time
T1 is. The microcomputer 220 monitors an exothermic
temperature Th of the exothermic resistor 211a, thereby

5   detecting a temperature change dth1 (Fig. 10A) per
predetermined time. When the temperature change dth1
per predetermined time is larger than a predetermined
value or when the exothermic temperature Th of the
exothermic resistor 211a enters a target heating

10 temperature range, the operation is regarded as a
normal operation and the output V6 of the I/O unit 225
is held at the low level.

The case of the voltage limiting operation in
Figs. 10D to 10F will now be described. In the

15 exothermic resistor 211a of a small heat capacity,
particularly, if a substance which absorbs the heat
generation of a fouling, water, or the like is
deposited onto the exothermic resistor portion, an
apparent heat capacity increases and the exothermic

20 temperature Th slowly increases until the fouling,
water, or the like is volatilized (Fig. 10D). The
maximum current continuously flows in the exothermic
resistor 211a. In this instance, a portion which
locally becomes a high temperature in the exothermic

25 resistor 211a appears depending on the depositing state
of the fouling, water, or the like, and there is a
possibility that the resistor formed on the thin film
deteriorates or the breakage of the thin film is caused

by a thermal shock. Therefore, the microcomputer 220 monitors the exothermic temperature Th of the exothermic resistor 211a, thereby detecting a temperature change dth2 (Fig. 10D) per predetermined

5   time. When the temperature change dth2 per predetermined time is smaller than a predetermined value and when the exothermic temperature Th of the exothermic resistor 211a is equal to or less than the target heating temperature range, the operation is

10 regarded as a voltage limiting operation and the output V6 of the I/O unit 225 is changed from the low level to the high level and held at the high level for a predetermined time (Fig. 10E). Thus, the NPN transistor 43 is turned on and the voltage V3 to be

15 applied to the bridge circuit can be reduced to VB2 (Fig. 10F). When the applied voltage V3 to the bridge circuit decreases, the exothermic temperature Th of the exothermic resistor 211a slowly rises. By decreasing the voltage, the burn-out state can be prevented and

20 the sudden increase or decrease in temperature can be prevented. A discriminating level of the temperature can be freely set in the microcomputer 220. When a heating limit time T3 elapses, the waterdrop is evaporated, the output V6 is changed from the high

25 level to the low level, the NPN transistor 43 is turned off, and the operation is returned to the normal operation. Although the time T2 which is required until the output V3 of the differential amplifier 15 is

finally stabilized becomes long by the execution of the voltage limiting operation, the deterioration or breakage of the resistor due to the sudden heating temperature change can be prevented, and the time T2

5 can be reduced to a time shorter than that which is required when the exothermic resistor 211a of a large heat capacity is used. Such a voltage limitation operating state apparently becomes a dead zone of the sensor and cannot be distinguished. However, by using

10 the microcomputer 220, information showing that the voltage limitation operating state due to the deposition of the waterdrop corresponds to the protecting operation of the sensor and is a special state instead of a failure of the sensor is sent to the

15 engine control unit or the like as an upper computer as diagnosis information of the sensor (an analog signal at the High or Low level, a digital signal such as an SCI [Serial Communication Interface], or the like), thereby enabling an erroneous operation or the like on

20 the engine control to be prevented.

As described in the above embodiment, by setting the resistor 211h to a resistor having a similar temperature coefficient arranged on the same substrate as that of the temperature compensation

25 resistor 211c as shown in Fig. 11, the temperature characteristic can be also provided for the limiting voltage.

According to the embodiment, particularly, in

case of using the exothermic resistor of a small heat

capacity, the heating state of the exothermic resistor

can be accurately monitored. By finely limiting the

heating state, there are effects such that the

5   deterioration or breakage of the resistor can be

prevented and the reliability of the hot-wire type air

flow meter can be improved for a long time.

The third embodiment of the invention will be

described with reference to Fig. 12. In the

10   embodiment, in a manner similar to Fig. 9, the hot wire

driving circuit 1 is constructed in such a manner that

a hoisten-bridge circuit is constructed by the

exothermic resistor 211a, temperature compensation

resistor 211c, and resistors 13 and 14, and a current

15   flowing in the exothermic resistor 211a is adjusted by

the differential amplifier 15 and transistor 16 so that

the potential difference at the middle point of the

bridge is equal to zero by the hoisten-bridge circuit.

A resistor 211 is constructed by forming a thin film

20   onto the silicon semiconductor substrate.

The voltages Vr1 and Vr2 at both ends of the

exothermic resistor 211a, a voltage Vr4 of the

temperature compensation resistor 211c, and the output

Vbi of the differential amplifier 2131 are inputted to

25   the analog/digital converter 221 of the microcomputer

220. In the microcomputer 220, the heating temperature

of the exothermic resistor 211a is obtained by an

arithmetic operation from the voltages Vr1 and Vr2 at

both ends of the exothermic resistor 211a, and a suction temperature is obtained by an arithmetic operation from the voltages Vr4 and Vr1 of the temperature compensation resistor 211c, thereby

5 detecting the ambient temperature (suction temperature) and the heating state of the exothermic resistor 211a. Further, the heating state of the exothermic resistor 211a is limited by the voltage limitation switching circuit 6 in accordance with an output V8 of a

10 digital/analog converter 224b. In the voltage limitation switching circuit 6, a differential amplifier 6101 for amplifying the output V8 of the digital/analog converter 224b is connected to the ground by network resistors 6102, 6103, 6104, and 6105

15 and resistors 6106 and 6107 for dividing the output voltage. In a manner similar to the foregoing embodiment, in the voltage limitation switching circuit 6, the output V3 of the differential amplifier 15 is limited to an output of the differential amplifier 6101

20 which is set by the output V8 of the digital/analog converter 224b via the diode 66 and resistor 6106.

In the normal operation, the output of the differential amplifier 6101 is generated as a maximum value. Thus, the output V3 of the differential

25 amplifier 15 is not subjected to the voltage limitation in the normal operation. On the other hand, by detecting the heating temperature and suction temperature of the exothermic resistor 211a and

discriminating the heating state, the output V8 of the digital/analog converter 224b is set in accordance with the suction temperature. The output V3 of the differential amplifier 15 can be digitally and freely

5 limited to the voltage which has already been set via the diode 66 and resistor 6106.

Similarly, in case of using the structure such that the temperature detecting resistors 211d, 211e, 211f, and 211g are arranged on both sides of the

10 exothermic resistor 211a, the local heating temperature of the exothermic resistor 211a can be also measured by intermediate voltages Vb1 and Vb2 between the temperature detecting resistors 211e and 211f and between the temperature detecting resistors 211g and

15 211d. Usually, when a waterdrop is deposited onto the exothermic resistor 211a heated to 100°C or higher, the temperatures of the temperature detecting resistors 211d, 211e, 211f, and 211g are changed in accordance with the depositing state, respectively. For example,

20 the fundamental depositing state of the waterdrop is discriminated by the heating temperature of the exothermic resistor 211a. In this instance, the size or the like of the waterdrop can be discriminated by observing the temperature changes of the temperature

25 detecting resistors 211d, 211e, 211f, and 211g. The time which is required until there is no waterdrop is presumed and the time corresponding to the dead zone of the sensor is sent to the engine control unit. On the

basis of it, the state of the sensor is discriminated, the output of the sensor is temporarily lightened and used for control or the like. Thus, a use efficiency of the sensor is improved and the engine control can be

5   more finely made.

According to the embodiment, particularly, in case of using the exothermic resistor of the small heat capacity, the heating state of the exothermic resistor can be accurately monitored. By finely limiting the

10 heating state, there are effects such that the deterioration or breakage of the resistor can be prevented, the reliability of the hot-wire type air flow meter can be improved more for a long time, and matching performance with the engine system is

15 improved.

Subsequently, Fig. 13 shows an example in the case where the resistor 211 constructed by forming a thin film onto the silicon semiconductor substrate is mounted on, for example, a multilayer ceramic substrate

20 or the like. The resistor 211 on the silicon substrate is mounted in a shaved frame of a ceramic substrate 300 and connected to a patterned circuit 302 on the ceramic substrate 300 via an electrode pad. Besides, an IC 303 obtained by integrating a circuit and a heater (second

25 resistive exothermic element) 301 for heating of the ceramic substrate 300 are provided on the silicon substrate 300. The heater 301 for heating is arranged so as to surround the resistor 211 on the silicon

substrate and controlled in accordance with the heating
state of the first exothermic resistor 211a on the
ceramic substrate. Although the second resistive
exothermic element 301 can be provided around the first
5 exothermic resistor 211a on the silicon substrate, it
is desirable to provide it outside of the diaphragm so
that the whole resistor 211 on the ceramic substrate
can be heated. By heating the peripheral portion of
the first exothermic resistor 211a in accordance with
10 circumstances as mentioned above, when a waterdrop is
deposited, the time which is required until the
waterdrop in the portion other than the diaphragm is
eliminated can be shortened. The ambient temperature
is detected and, in case of a low temperature, the
15 whole resistor 211 on the silicon substrate is first
preheated by the second resistive exothermic element
301. Thus, for example, the heating time of the first
exothermic resistor 211a at the time when an ice is
deposited can be remarkably reduced. Particularly, it
20 is effective in the case where the electric power which
is supplied to the first exothermic resistor 211a is
limited so as not to break the diaphragm.

     According to the embodiment, by controlling
the heating temperature of the second resistive
25 exothermic element in accordance with the ambient
temperature, the time of the dead zone of the hot-wire
type air flow meter due to the limitation of the
heating state can be reduced without breaking the first

exothermic resistor 211a on the diaphragm.

There is an effect such that the performance
can be improved while assuring the reliability as
mentioned above.

5   The third embodiment of the invention will
now be described with reference to Fig. 14. A hoisten-
bridge circuit based on the constant voltage Vcc
driving is constructed by: the exothermic resistor 11;
a heating portion of the current detecting resistor 13;

10   a temperature detecting resistor (heating temperature
sensor) 111 arranged on the side of the exothermic
resistor 11 so as to be mounted on the same substrate
as that of the exothermic resistor 11; the temperature
compensation resistor 12; and the resistors 13 and 14.

15   The hot wire driving circuit 1 is constructed in such a
manner that a current flowing in the exothermic
resistor 11 is adjusted by the differential amplifier
15 and transistor 16 so that the potential difference
at the middle point of the bridge is equal to zero by

20   the hoisten-bridge circuit. When the heating
temperature of the exothermic resistor 11 is low, the
output of the differential amplifier 15 increases and
the apparatus operates so as to heat more. With this
construction, the resistance value of the exothermic

25   resistor 11 is controlled so as to be constant, namely,
the temperature is set to a predetermined value
irrespective of the air flow rate. In this instance,
the signal corresponding to the air flow rate by the

exothermic resistor 11 is inputted to the zero span

circuit 2. The zero span circuit 2 is constructed by

the differential amplifier 21 and resistors 22, 23, 24,

25, 26, and 27. The above construction is a mere

5 example and a system for detecting the flowing

direction by using the temperature difference as

described above can be also used as output means of the

signal corresponding to the air flow rate.

Particularly, the differential amplifier 68

10 is prepared as second bridge detecting means for

detecting the potential difference at the middle point

of the bridge in order to detect the depositing state

of the waterdrop, and the simplified voltage limitation

switching circuit 6 is provided as a second limiter for

15 limiting the output voltage V3 of the differential

amplifier 15 in accordance with a detection result.

The simplified voltage limitation switching

circuit 6 is constructed by the diode 66, a resistor

69, and the like. The output of the differential

20 amplifier 15 is connected to the output of the

differential amplifier 68 through the resistor 17,

diode 66, and resistor 69. The voltage to be limited

is determined by a voltage dividing ratio of the

resistors 17 and 69.

25 Even in such a construction in which the

heating unit and the bridge circuit of the constant

temperature control are separately provided, effects

similar to those in the above embodiment can be

obtained by detecting the depositing state of the waterdrop and limiting the voltage in accordance with the output state of the differential amplifier 68 in a manner similar to the above embodiment.

5   According to the embodiment, since the applied voltage to the exothermic resistor can be limited by the simple circuit construction, there is such an effect that the reduction of the reliability such as deterioration or breakage of the resistor can

10   be prevented by low costs.

Even in case of controlling the applied voltage V2 of the bridge by the pulse driving, an effect similar to the effect which is obtained by the linear voltage control described in the embodiment so

15   far can be obtained. For example, by limiting either the applied voltage V2 to the bridge or the driving current to the predetermined value and by limiting the pulse width corresponding to the magnitude of the limited voltage (or current) to a predetermined value,

20   the deterioration or the like of the resistor due to the overheating can be prevented.

Although not shown, as another embodiment, there is an internal combustion engine constructed by: a suction pipe in which the air including liquid

25   droplets flows; an air flow meter having a protecting circuit in the case where the liquid is deposited to a detecting device; a fuel injection valve; and a controller for controlling the fuel injection valve on

the basis of an output of the air flow meter.

According to the embodiment, particularly, in case of using the exothermic resistor of the small heat capacity, by preventing the maximum heating state from continuing in excess of the inherent heat capacity of the exothermic resistor, the deterioration or breakage of the resistor can be prevented and there is such an effect that the reliability of the hot-wire type air flow meter can be assured and, at the same time, the response speed upon activation of the air flow rate when the power source is turned on can be improved. Thus, there are such effects that the air flow rate at the start of the engine of the automobile can be rapidly measured and a quantity of exhaust gas at the time of start of the engine can be reduced.

According to the embodiment, particularly, in case of using the exothermic resistor of the small heat capacity, by distinguishing and detecting the case where a waterdrop, an oil droplet, or the like is deposited onto the exothermic resistor portion and the normal case where there is no deposition, there are such effects that the heating state is limited only in the case where the waterdrop, oil droplet, or the like is deposited on the exothermic resistor portion without narrowing the inherent measuring range of the flow rate, the deterioration of the resistor can be prevented, and the reliability of the hot-wire type air flow meter can be assured and, at the same time, the

response speed in response to the leading edge of the

air flow rate when the power source is turned on can be

improved. There are, consequently, such effects that

the air flow rate at the start of the engine of the

5 automobile can be rapidly measured, and a quantity of

exhaust gas at the start of the engine can be reduced.